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Effect of Trench-Composted Organic Wastes on The Growth Performance, Phytochemical Properties, and Disease Occurrence of *Capsicum frutescens*

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Abstract
Capsicum frutescens is one of the most economically important crop in Malaysia. Despite growing interest in animal manures and BSFF as sustainable alternatives to chemical fertilizers, comparative data on their effects on C. frutescens remain limited. To address this gap, this study aimed to evaluate the impact of five organic wastes including goat manure, cow dung, chicken manure, Red Tilapia fish carcass, and Black Soldier Fly frass (BSFF) using trench composting on the soil fertility, growth, yield, and phytochemical properties of the *Capsicum frutescens* (bird's eye chilli). The raw organic wastes were placed in trenches with biochar and diluted effective microbes, composted and applied to chili plants that has been arranged in plots compared to unamended control. All organic waste treatments significantly improved soil nutrient content relative to the control. These findings confirm that trench-composted animal wastes and BSFF are viable, environmentally friendly alternatives to chemical fertilizer for improving soil fertility and chili productivity, although raw, high-moisture wastes such as fish carcasses require proper pre-treatment to reduce disease risk. Further trials under controlled greenhouse conditions and over extended periods are recommended to confirm these results and to support sustainable agriculture in Malaysia.

Keywords: *Capsicum frutescens*; animal manures; Black Soldier Fly Frass; plant growth; phytochemical properties.

Introduction

The increasing demand for livestock and food production has resulted in large amounts of animal waste. This waste poses several environmental impacts including soil contamination, water pollution and greenhouse gas emission. Despite these concerns, animal waste contains some valuable nutrients such as nitrogen (N), phosphorus (P) and potassium (P) that are important for agricultural activities by developing into organic fertilizers (Andini et al., 2024).

The use of insects such as black soldier fly also reported their potential to enhance soil fertility and plant growth (Adetunji et al., 2023). The use of locally available organic waste as a compost gives several benefits including reduced landfill volumes, decrease methane emission and odour as well as reducing the dependency on imported fertilizers (Manea et al., 2024).

Despite these advantages, conventional fertilizers remain the dominant practices in *Capsicum frutescens* cultivation in Malaysia, which become one of the Malaysian crops that have economic significance and are grown for their pungency and culinary purposes (Rahim et al., 2024). The prolonged use of this fertilizer will result in soil degradation, environmental pollution and dependency on non-renewable inputs (Sharma and Singh, 2020; Zainuddin et al., 2021). By filling this knowledge gap, this research can provide valuable insight for farmers and stakeholders on their effectiveness and practical value of animal manures and BSF frass, potentially moving towards ecologically friendly methods and reducing food waste through circular economy practices and contributing to Malaysia's goals for sustainable agriculture and food security.

This study therefore aimed to determine the effect of trench-composted organic wastes on soil fertility, morphological characteristics of *Capsicum frutescens* grown using the trench-composting technique, assess the phytochemical properties of the fruit and leaves produced, and isolate the plant pathogen associated with disease symptoms observed in the crop, with the scope limited to comparing the five waste types.

The findings are significant in offering farmers and stakeholders practical evidence on renewable alternatives to chemical fertilizer, supporting Malaysia's Sustainable Development Goal 2 (Zero Hunger) through improved crop productivity, SDG 12 (Responsible Consumption and Production) through waste valorization, and SDG 13 (Climate Action) through reduced reliance on chemical fertilizer (Patunah & Pradani, 2024).

Materials and methods

Organic wastes (cow dung, goat dung and chicken dung), fish wastes (Red Tilapia fish carcass) and BSF frass were collected from farms in Kulai, Pekan Nenas and UTM Skudai and composted using trench-composting method, where each of organic waste was weighed by taking into account the bulk density and nutrient content of the respective organic wastes (9.90 kg cow dung, 3.30 kg goat dung, 2.64 kg chicken dung, 1.65 kg fish wastes and 0.99 kg BSF frass per plot) and topping the stockpiles with Bokashi EM1 solution to accelerate fermentation and biochar charcoal ash to reduce nutrient loss, neutralise acidity (Hamidi et al., 2021). Both fish wastes and BSF frasses were applied in lower quantities due to higher nutrient content, which would cause phytotoxicity if applied in higher quantities (J. Zhang et al., 2023). The pH and temperature of the soil were monitored using a soil meter until they reached stability (maturity) and then chili saplings were transplanted with six replicates per treatment. A 1 kg soil sample was collected from each plot once the plants reached maturity and sent to the UTM Pagoh Analytical Laboratory for physicochemical analysis of the soil, and the soil sensor was used to measure the soil pH, temperature, moisture, NPK, and EC at seven points in the field once a week for 9 weeks.

The collected data included morphological and phytochemical characteristics. Plant height (using measuring tape), leaf and branch number (counting by hand), and stem diameter (using a vernier caliper) were measured weekly until week 9 and fruit numbers, length, and weight were measured at harvest in week 9 (Du et al., 2021; N et al., 2023). Fruit was dried, ground and extracted in 80% ethanol for total phenolic content (Folin-Ciocalteu assay absorbance at 765 nm against a gallic acid curve) and total flavonoid content (aluminium chloride assay absorbance at 430 nm against a quercetin curve), leaf chlorophyll was monitored non-destructively using a SPAD meter and chlorophyll a/b and carotenoids were extracted in 80% acetone and read spectrophotometrically at 664, 645 and 450 nm in 96-wells plated (Sari et al., 2023; Saifullah et al., 2023; Saptiningsih et al., 2023). To isolate the fungal pathogen, leaf tissue surface-sterilized and cultured on Potato Dextrose Agar and all measured parameters compared with the control by two-way ANOVA at $p < 0.05$, followed by Bonferroni post-hoc tests and Pearson correlation to evaluate relationships among parameters were used.

Results and discussion

Soil Fertility

The mean value of pH inside soils over 9 weeks is shown in Figure 1. Soil pH was significantly affected by treatment ($p = 0.025$). The pH for the control was the highest (6.69) and the organic-waste treatments were slightly acidic ranging from 6.30 for cow dung to 6.44 for both chicken manure and Red Tilapia carcass. The treatments were generally mild acidity to near neutral (6.1-7.3) which is recommended for chili growing (Ak et al., 2020; Mc & Nadaf, 2025). This mild acidification is believed to be due to the fact that the trial period was only nine weeks, too brief for organic acids to be completely mineralized and buffered towards neutral pH in the early stages of microbial breakdown of the freshly buried non-matured waste, which is required to produce the alkalinisation reported for longer-term matured composts.

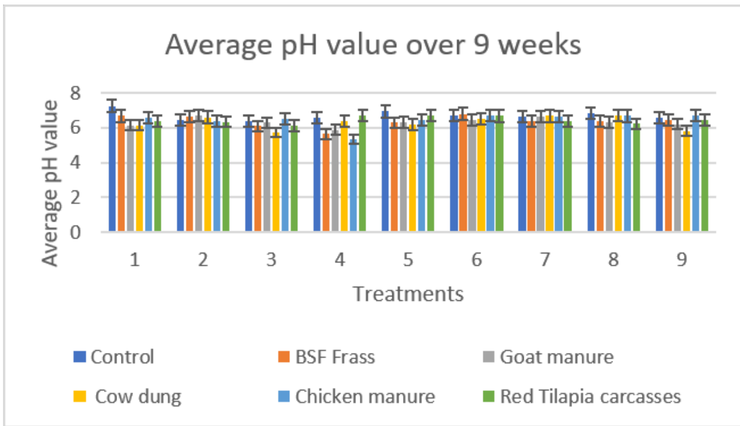

Figure 1 Average soil pH value over 9 weeks

Based on Figure 2, There was a significant difference in mean soil temperature among the treatments ($p < 0.001$), with cow dung having the highest average (28.32°C) and BSFF having the lowest (27.63°C) which was near the control (27.70°C). Soil temperature remained relatively stable with a narrow range 26°C to 30°C over a 9-week period.

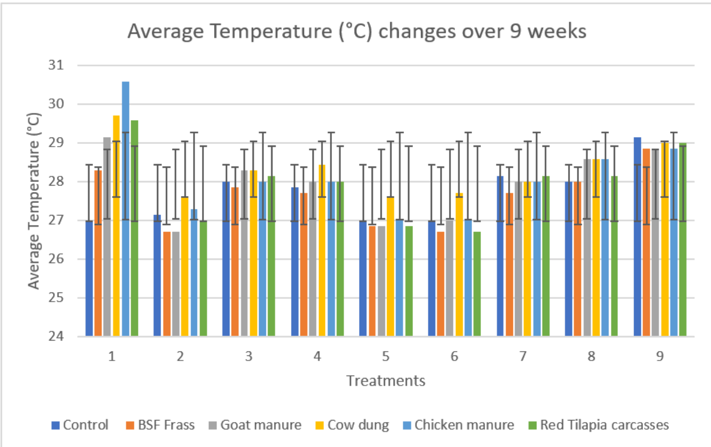

Figure 2 Average soil temperature (°C) around 9 weeks

Moisture content shown in Figure 3 did not differ significantly between treatments ($p = 0.284$), but varied strongly by week ($p < 0.001$) and by the treatment-week interaction ($p = 0.007$). There was more variation in the treatments in the first week, however by week 3, they were all close to saturation (89-90%), presumably due to the high amount of rainfall that the treatments had received on the open-air plots, which is the optimum moisture range reported for the bird's eye chili. The increasing soil moisture above the optimum moisture content must be driven by the rainfall effect. Since the study was conducted on open space, the experimental plot was prone to the heavy rainfall and gave direct water input to the soil and pushed moisture levels above the plant's ideal range. Based on Table 1, the initial differences were due to the water-holding capacity and organic matter content of each waste, with the highest water-holding capacity and organic matter content being in the chicken manure and Red Tilapia carcass, and the lowest in the goat manure. High in water holding-capacity and organic matter are useful because they can improve soil porosity and moisture preservation (Gayathri et al., 2020).

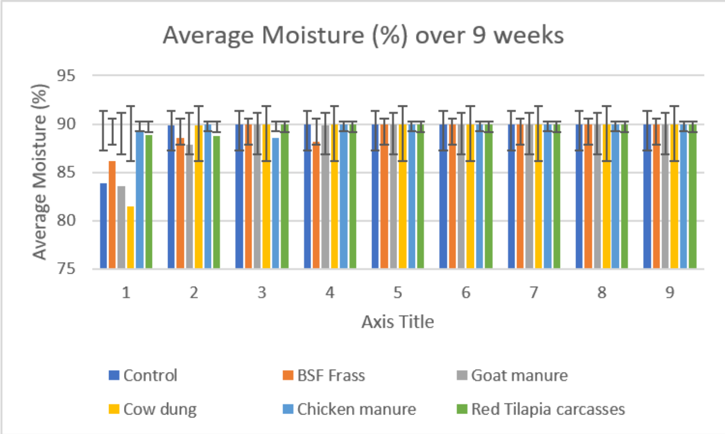

Figure 3 Average moisture (%) value over 9 weeks

Table 1: Water holding capacity (%), bulk density (g/cm³) and organic matter (%) of organic wastes (Result from Analytical Laboratory, UTM Pagoh).

Treatment	Water holding capacity (%)	Bulk density (g/cm^3)	Organic matter (%)
BSF Frass	48.24	0.52	20.56
Goat manure	44.24	0.54	14.98
Cow dung	44.24	0.52	19.63
Chicken manure	48.24	0.46	19.91
Red Tilapia carcasses	56.12	0.51	19.83

According to Figure 4, EC rose significantly with organic amendment ($p < 0.001$). Among the treatments, BSF frass show the lowest EC value of 0.364 mS/cm. In contrast, slight increase of EC value under BSF frass is in line with frass being a lower salinity organic input than raw manure, since the larvae partially metabolise and structure the substrate during rearing rather than simply concentrating excreted mineral salts.

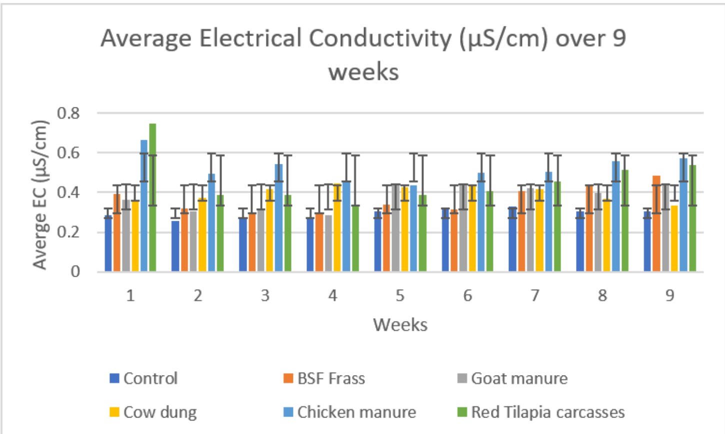

Figure 4 Average EC value (µS/cm) over 9 weeks

Although trench composting organic wastes was generally found to increase the fertility of the soil, not all treatments were seen to consistently outperform the control. For total nitrogen, the values of all the treatments were higher than the control values, which means that all the waste treatments contributed to nitrogen enrichment. However, for phosphorus and potassium, some treatments performed less effectively. Cow dung recorded the lowest available phosphorus (271.40 mg kg^{-1}), suggesting a slower release of phosphorus due to the gradual mineralization of organic phosphorus compounds (J. Zhang et al., 2022). Similarly, BSF frass had the lowest exchangeable potassium (1.74 mEq 100 g^{-1}), indicating that it supplied less potassium than the other organic wastes (Table 2). The results indicated that all treatments had ameliorating effects on soil fertility, but variations in nutrient composition and mineralization rates resulted in differences in the availability of N, P and K and hence the release of nutrients between the organic waste treatments.

Table 2: Water holding capacity (%), bulk density (g/cm^3) and organic matter (%) of organic wastes (Result from Analytical Laboratory, UTM Pagoh).

Treatment	Total Nitrogen (N) (%)	Available Phosphorus (P) (mg/kg)	Exchangeable Potassium (K) (mEq/100g)
BSF Frass	0.42	1083.00	1.74
Goat manure	0.43	555.00	1.88
Cow dung	0.50	271.40	3.08
Chicken manure	0.56	590.40	3.03
Red Tilapia carcasses	0.36	632.60	2.45

The soil NPK values monitored weekly corresponded well with the physicochemical properties of the trench-composted organic wastes. Although BSF frass had the highest available phosphorus in the laboratory analysis, it exhibited lower nitrogen and potassium levels, and therefore provided a slower nutrient release during the cultivation period. Likewise, cow dung and goat manure also had moderate NPK values over time, indicating their slower decomposition rates and gradual nutrient mineralization, while the control treatment consistently recorded the lowest nutrient levels due to the absence of organic amendments.

Morphological characteristic of *Capsicum frutescens*According to Figure 5 and 6, chicken manure produced the tallest plants by week 9 (49.83 cm) and the largest stem diameter (0.61). This organic waste also recorded the highest leaf count (214.5) and the most branches (mean 5.0). All showed highly significant treatment effects with $p < 0.001$ for each parameter, consistent with the treatment's superior nitrogen, phosphorus, and potassium supply driving shoot elongation, leaf expansion, and stem thickening (Chemweno et al., 2025). Goat manure consistently produced the weakest structural growth, including the lowest stem diameter (0.34 cm), aligning with its comparatively lower potassium release.

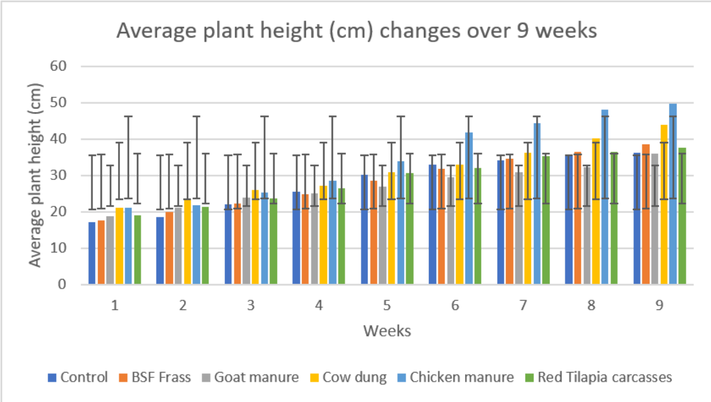

Figure 5 Average plant height (cm) over 9 weeks

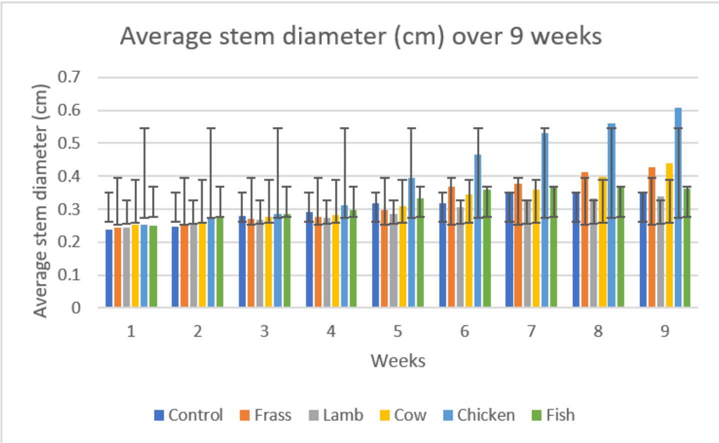

Figure 6 Average stem diameter (cm) over 9 weeks

Fruiting began by week 5–6 for most treatments, where control and BSFF plants fruited earliest, while Red Tilapia carcass plants did not fruit until week 7. Despite its clear vegetative advantage, chicken manure's superior growth did not translate proportionally into harvested yield. It produced the most fruit overall (about 12) but converted only 25% into harvested fruit, whereas BSFF, with 11 fruits produced, converted roughly 45%. Goat manure and cow dung each yielded about 7 fruits, while the control and Red Tilapia carcass yielded only about 2, with the fish carcass treatment ultimately producing no harvested fruit at all due to severe fungal infection (Figure 7).

This pattern matches the reported trade-off in Solanaceous crops where excess nitrogen shifts resource allocation toward vegetative growth (denser canopy, shaded fruiting sites) at the expense of fruit set Tiwari et al., 2022). Chicken manure and BSFF produced the longest and heaviest fruit (4.8 cm/0.697 g and 4.62 cm/0.66 g respectively), consistent with their higher soil potassium, while cow dung produced the shortest and lightest fruit (4.4 cm/0.358 g), likely linked to its complete lack of branching and consequently smaller fruit-bearing area.

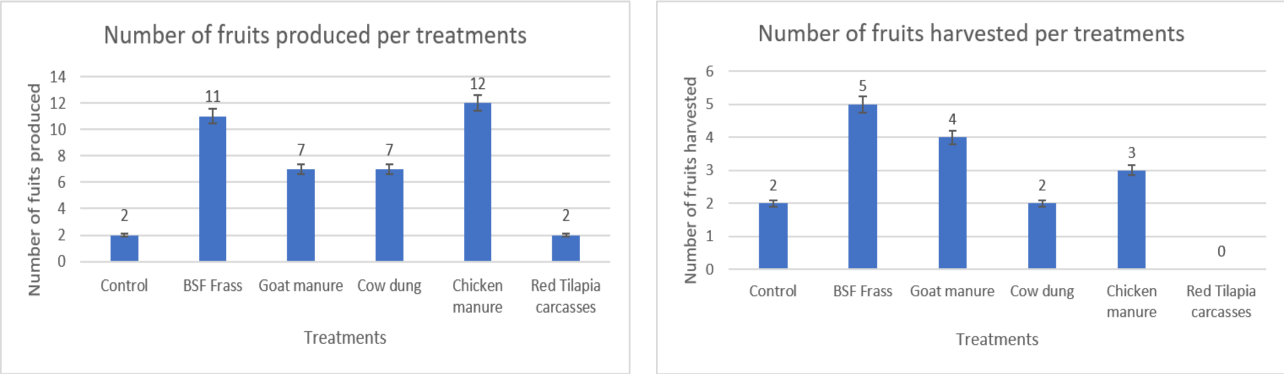

Figure 7 Average number of fruits produced and total number of fruits harvested per treatment

Phytochemical Properties of *Capsicum frutescens*

Based on Figure 8, total phenolic content (TPC) was highest in goat manure fruit (1709.80 mg GAE/g), followed by BSFF (1207.80), cow dung (837.30), and lowest in chicken manure (654.90) and the control (264.70), TPC could not be measured for Red Tilapia carcass due to failed fruit set. This ranking directly reverses the vegetative growth ranking, in which chicken manure led every parameter. Total flavonoid content (TFC) followed a similar but less pronounced pattern, highest in BSFF (48.88 mg QE/g), followed by cow dung and goat manure, and lowest in chicken manure (43.88), though still above the control (38.88).

These results fit a growth–defence trade-off, where chicken manure's nitrogen surplus favoured vegetative biomass over secondary metabolite synthesis, while goat manure and BSFF's more moderate, balanced nutrient release combined with goat manure's higher micronutrient content and BSFF's chitin-driven elicitation of plant defence responses favoured phenolic and flavonoid accumulation instead (Sun et al., 2020; Kenchanna et al., 2024).

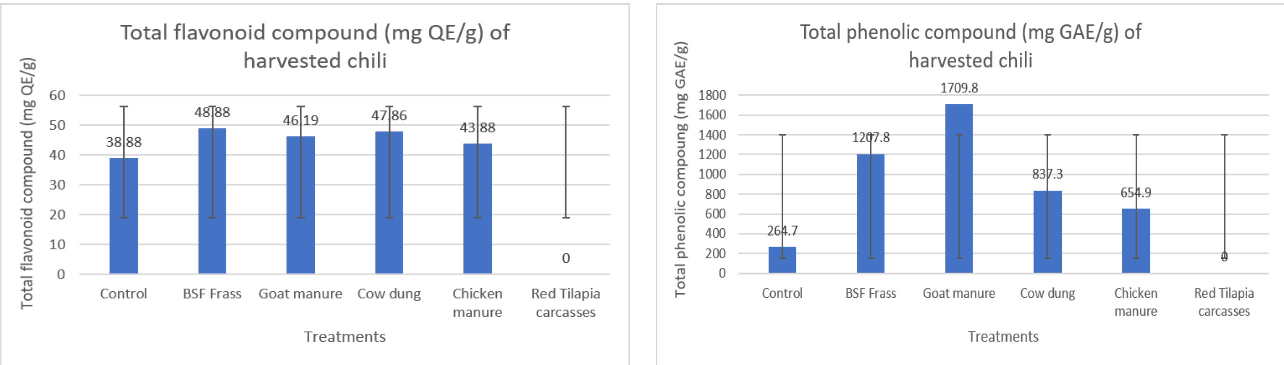

Figure 8 Total phenolic anf flavonoid content

Based on Figure 9 and 10, leaf pigment analysis mirrored the fruit phytochemical trend, the unamended control had the highest chlorophyll a and b (16.091 and 4.925 µg/ml), while chicken manure had the lowest (13.617 and 4.427 µg/ml) despite producing by far the most leaves, consistent with a pigment-dilution effect, where nitrogen-driven leaf expansion outpaces pigment biosynthesis per unit tissue. BSFF produced the highest carotenoid concentration (6.300), while fish carcass produced the lowest (3.321).

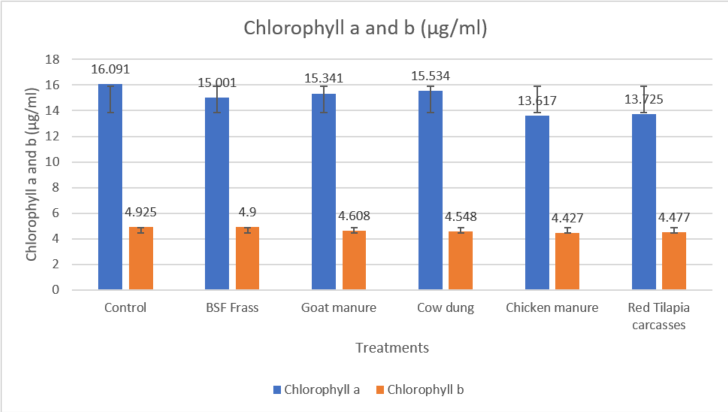

Figure 9 Chlorophyll a and b on leaves

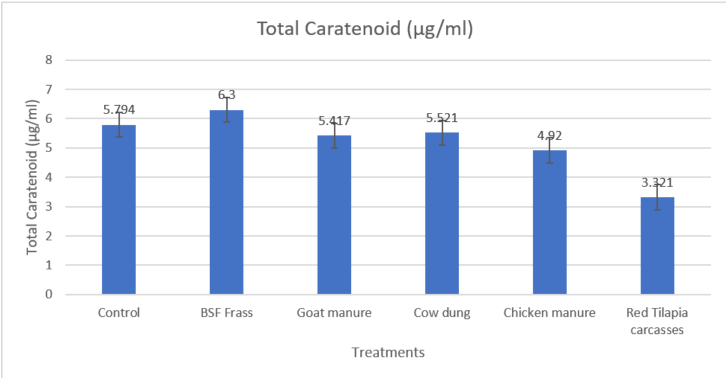

Figure 10 Total carotenoid (μg/ml) on leaves

In Figure 11, weekly SPAD chlorophyll readings, however, showed chicken manure with the highest mean greenness (35.99) across the nine weeks, reflecting active nitrogen status during vegetative growth rather than final pigment concentration per gram of tissue at harvest, the two measures capture different things (real-time greenness versus end-point extracted pigment) (Vishwakarma et al., 2023). The Red Tilapia carcass treatment showed the steepest SPAD decline, from 37.85 in week 5 to 13.67 by week 9, coinciding with the onset of fungal disease symptoms in week 6 and the resulting loss of leaf physiological function (Ekwomadu & Mwanza, 2023).

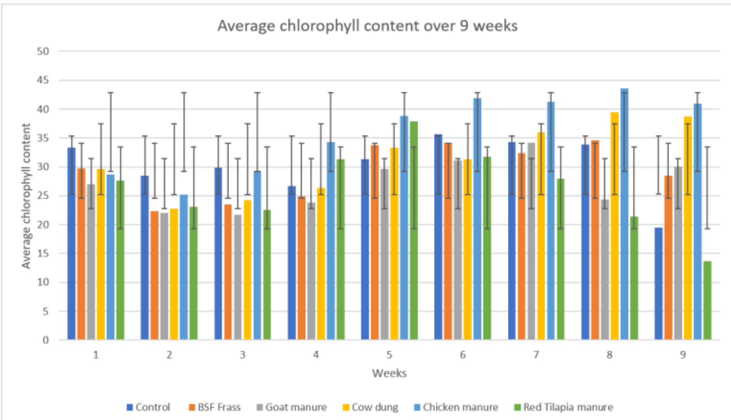

Figure 11 Total carotenoid (μg/ml) on leaves

Fungal Infection of *Capsicum frutescens*

Although Red Tilapia carcass treatment provided the second-highest soil nitrogen, phosphorus, and potassium levels, it triggered severe fungal infection that ultimately prevented fruit formation. This is consistent with reports that nutrient-rich, high-moisture substrates favour pathogenic over mutualistic soil fungi. Because the fish carcasses were buried fresh without prior composting, the high-protein, high-moisture material was applied directly to the root zone, and this risk was compounded by heavy rainfall during the trial that kept the plot excessively wet, which known trigger for fungal disease in Capsicum crops.

Based on Figure 12, the presence of fungal infection has been proved by the colony morphology on the surface of the agar. The colony shown is consistent with vigorous hyphal growth extending upward from the PDA agar surface, the colony colour appeared pure cottony white, and the pigmentation of the colony was yellow to dark brown, which suggests that it has been grown on PDA (Thesiya et al., 2020).

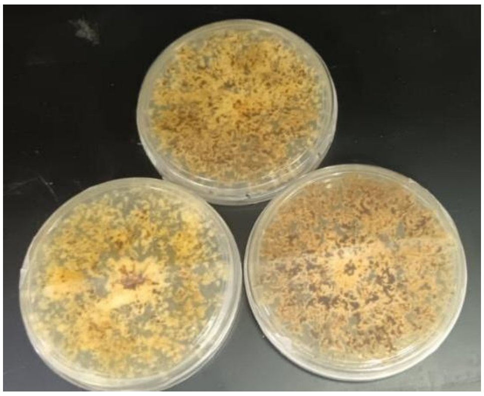

Figure 12 Total carotenoid (µg/ml) on leaves

Conclusion

Overall, it can be concluded that use of trench-composted organic wastes significantly boosted soil fertility, the growth and yield of *Capsicum frutescens*, and influenced the phytochemical properties of the crop. The chicken manure was found to be the best overall performance and the BSF frass was found to be a promising sustainable alternative fertilizer. In spite of not being able to complete the phytochemical analysis of the Red Tilapia carcass treatment due to extensive fungal infestation, the pathogen that caused the infestation was successfully isolated on the PDA medium. Further investigations should be carried out in the controlled greenhouse under longer crop duration in order to reduce the occurrence of disease and to get more representative growth and yield data. The soil NPK values monitored weekly corresponded well with the physicochemical properties of the trench-composted organic wastes. Laboratory analysis found that the BSF frass with the highest available phosphorus levels also contained lower amounts of N and K, which meant that it had a slower nutrient release during the cultivation period. Similarly, the cow dung and goat manure also had moderate NPK levels over time, signifying that the dung had slower decomposition rate and a gradual nutrient mineralization; for the control, the nutrient level was always low because it had no organic amendment.

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